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ABSTRACT

This symposium report presents a summary of research on the affect of aircraft noise on the classroom environment revealing that aircraft noise can interfere with learning in the following areas: reading, motivation, language and speech acquisition, and memory. The strongest findings are in the area of reading, where more than 20 studies have shown children in noise impact zones are negatively affected by aircraft noise. Additionally, summaries of studies are provided showing negative impacts of aircraft noise on memory and cognitive performance as measured by standardized test scores. The paper concludes with brief descriptions of where more research is needed and recommendations from the Federal Interagency Committee on Aviation Noise. (GR)

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Federal Interagency Committee on Aviation Noise FICAN Position on Research into Effects of Aircraft Noise on Classroom Learning

September 2000

Research on the effects of aircraft noise on children's learning suggests that aircraft noise can interfere with learning in the following areas: reading, motivation, language and speech acquisition, and memory. The strongest findings to date are in the area of reading, where more than 20 studies have shown that children in noise impact zones are negatively affected by aircraft. Recent research confirms conclusions from studies in the 1970s showing a decrement of reading when outdoor noise levels are at an L_{eq} of 65 dB or higher. It is also possible that, for a given level of L_{eq}, the effects of aircraft noise on classroom learning may be greater than the effects of road and railroad traffic. Members of FICAN are in agreement on the following: (1) Further work should be done to establish whether school day L_{eq} is the appropriate measure for determining the effect of aircraft noise on classroom learning. (2) In the absence of appropriations for specific research, FICAN encourages "before" and "after" evaluations of the effectiveness of noise mitigation in schools. (3) FICAN will undertake a pilot study to evaluate the effectiveness of school sound insulation programs. (4) FICAN supports the work of the American National Standards Institute in its efforts to develop a standard for classroom noise.

INTRODUCTION

The Federal Interagency Committee on Aviation Noise (FICAN) has considered the issue of the effects of aircraft noise on children's learning, including: reviewing relevant research; inviting U.S. researchers to a FICAN meeting; and conducting a symposium, to which prominent international researchers were invited to present their findings. The symposium was held during the University of California's International Airport Noise Symposium, San Diego, February. 2000. Speakers at the symposium included: Dr. Gary Evans of Cornell University, Ithaca, NY; Dr. Staffan Hygge of the Royal Institute of Technology, Gavle, Sweden; Dr. Stephen Stansfeld, University of London, UK; Dr. Mary Haines, University of London, UK; Mr. Lou Sutherland, Consultant in Acoustics, California; and Mr. David Lubman, Consultant in Acoustics, California. Their presentations can be found on the FICAN web site (www.fican.org). This paper presents a summary of the research presented at the symposium, and FICAN's recommendations.

BACKGROUND

At the symposium, Dr. Gary Evans presented a summary of research on the effects of noise on children and learning. Research to date supports the following findings:

- ***Reading*** The strongest finding of a relationship between aircraft noise and learning is in the area of reading. More than 20 studies have found that children in noise impact zones are negatively affected by aircraft noise. Researchers are now trying to identify a mechanism to explain the cause-and-effect relationship of the observed delay.

- ***Motivation*** Approximately a dozen laboratory and field studies indicate reduced task persistence in relation to uncontrollable noise. Some of the research has identified a condition of "learned helplessness": if one is continually put in a situation where he or she has little control over the environment, he or she may "learn" helplessness.

- ***Language and Speech*** A small number of studies suggest delayed language acquisition and interference with speech perception in noisy areas. These data are potentially important because they may provide a model for understanding the linkage between noise and reading. A fundamental building block of reading is language – increasingly, research in

psycho-linguistics shows language acquisition is critical to developing reading skills. When a child is acquiring language in situations where speech interference is common, it is quite possible that delayed language may result, leading to reading delay. This is especially true of vulnerable children, such as those with hearing problems and those who are learning in a non-native language.

- ***Memory*** A few studies suggest deficits in short-and long-term memory recall in the presence of noise, particularly for more complex material under noise. An interesting finding that has been replicated with studies of adults is that the recall is diminished more when the material is complex. So if the task is easy, noise has little effect, but if it is demanding, noise has a deteriorating affect.

RECENT RESEARCH

A number of recent studies support the general findings presented above. These include: studies of the effects of noise on memory, the effects of noise on cognitive performance as measured by standardized test scores, and studies of the effects of aircraft noise on vulnerable populations.

Effects on Memory: Dr. Staffan Hygge

Dr. Staffan Hygge has conducted a number of studies that address the issue of the effect of noise on memory and recall.

Classroom noise study In this experiment involving children in their own classrooms, approximately 1,500 students were exposed to a variety of controlled noise sources (tape recordings), including: aircraft noise, rail noise, road traffic (highway) noise, and a combination of the three. The students were exposed to the same total noise level (Lmax 76 dBA, Leq 66 dBA for 15 minutes, 24-hour Leq of 42 dBA), and events at approximately the same rate (8 events in 15 minutes). Testing was always conducted in the morning, at the peak of students' intellectual alertness. Testing included three tests, under either noise or silence conditions; test subjects' exposure was reversed on the second test wave (i.e., students tested in silence in the first wave were exposed to noise in the second wave). The results showed significant deterioration in recall for the students exposed to both aircraft and highway noise conditions, but there was no effect from rail. When the test noise level was turned down to Leq 55 dBA, the effect of the road traffic dropped out, but there was still an effect from aircraft noise. This suggests that airport noise effects are worse than highway noise effects, which are worse than rail effects.

Munich Airport Study In this study, researchers took advantage of the shut down of the old Munich Airport and the opening of the new Munich Airport. The study followed 350 children at schools near both airports. At the start of the study, children were 9 years old. Students were matched for highly exposed and less exposed to aircraft noise. The students were tested on a host of measures, including non-auditory health effects beyond cognition and memory. The test for long term memory was very similar to the one conducted in the classroom noise study. Initially had a disadvantage at old airport, which disappeared after the old airport was shut down; on the other hand, children near the new airport showed deteriorating cognition levels over time.

Second classroom noise study In this study, high school students were exposed to noise patterns that included either "irrelevant" (nonsense) speech or road traffic noise. The goal of the study was to evaluate what kinds of memory systems and processes are affected by noise. Results showed that recall is sensitive to noise – lower scores for both traffic noise and silence, and the same reduction with irrelevant speech. On attention, more errors were observed in both noise conditions than in silence. Conclusions from all three studies taken together suggest: (1) There appear to be effects of noise on long term

recall, particular with aircraft noise exposure. It does not seem to matter if exposure is acute (short-term) or chronic (long-term) noise exposure. (2) The effects may be reversible – children originally exposed to aircraft noise in the Munich exposed improved when the airport was shut down. The results of these studies put researchers in a position to evaluate two possible patterns of causation: in the first, one assumes that the primary effect is on physiology – heart rate rises, then other non-auditory responses follow. An alternative theory supporting stress research suggests that the cognitive system is affected first, which must overcome stressful situation, ultimately resulting in changed perception and quality of life.

Effects on Health and Cognitive Performance: Dr. Stephen Stansfeld and Dr. Mary Haines

Dr. Stansfeld and Dr. Haines presented the results of three studies dealing with the effects of aircraft noise on children's health and cognitive performance in the vicinity of Heathrow Airport: the Schools Environment and Health Study, the SATs Study, and the West London Schools Study.

Schools Environment and Health Study This study was commissioned as part of an Inquiry investigating the construction of fifth terminal at Heathrow. The aim of the study was to examine the effects of chronic noise exposure on children's health and cognition. The researchers evaluated baseline (1996) reading comprehension and noise annoyance, cortisol secretion (to identify possible stress) and mental health indicators (anxiety and depression). At follow-up (1997), the researchers tested reading, sustained attention, annoyance, and perceived stress. One of the objectives of the study was to test the hypothesis that interference with sustained attention is a possible causal factor in reduced cognitive performance; that is, if attention levels are decreased, lower reading skills may result. Researchers also wanted to evaluate vulnerable populations by controlling for socio-economic status (SES). Researchers evaluated primary age children aged 8- 11 in four schools near the airport, matched to four schools with lower noise levels. Tests were administered in the classroom; simultaneous noise measurements at the schools were conducted, and home noise levels were determined from Civil Aviation Authority (CAA) contours. Schools were matched for SES, other background noise, and ethnicity. The results of the analysis showed that the high-noise area schools contained significantly more non-white, non-English speaking, socially deprived children. Reading comprehension scores showed that in the high noise group, children were statistically significantly delayed – approximately a six-month difference in reading age. Children in the high-noise schools were also more highly annoyed by aircraft noise; however, children's annoyance response did not match parents' response. Measurements of cortisol levels did not show significant differences either at the beginning or end of testing; this may suggest cortisol is not appropriate hormone to evaluate for stress levels in children. Other behavioral testing shows that aircraft noise does not appear to increase depression or anxiety. At follow-up (one year later), children exposed to high levels of noise had poorer reading, and sustained attention; however, no there was no significant finding that attention was underlying reason. The stress responses replicated the effect of annoyance: children exposed to high noise had greater annoyance. Researchers wanted to clarify this more: could it be that children in high-noise areas had more stress responses? Researchers tested children on how would they feel if stressful life events happened to them. The children in the high noise schools reported higher responses (would feel more stressed in a stressful situation), although they did not have significantly more *actual* stress events in their lives. This may be an indicator of coping style – perhaps supporting the "learned helplessness' theory. How did children adapt over the year? Test scores were analyzed by adjusting for baseline performance. It appears that the effects increased over time – progress by students in high noise schools was lower than progress for children in low noise group. However, when adjusted for socioeconomic status and main

language spoken at home, the effect was eliminated – this may be a result of sample size. In terms of annoyance, the effect stayed the same. In summary, annoyance effects appeared to stay the same, whereas reading effects seemed to worsen over the year.

Scholastic Aptitude Study (SATS) This was a multi-level modeling study looking at effects of aircraft noise on the test results in reading, mathematics, and science. The study examined 128 primary schools around Heathrow Airport, trying to answer the following questions: (1) whether previous associations between noise level and cognitive performance were confounded by either social class or school quality, and (2) does noise affect language-based tasks more than math or science tasks. For eleven-year olds, researchers evaluated 11,000 scores from 128 schools exposed to a range of aircraft noise exposure, based on CAA contours for 16-hour Leq, in 3 dB bands – to try to get a dose response curve (noise levels ranged from 54 dBA to 72 dBA).The Effects of Noise on Children's Learning page 4 The statistical model used to evaluate the data adjusted for sex, year (age), type of school (public, private), and social deprivation (% eligible for free school meal). Researchers did not find a main effect on English, but did find a main effect on Mathematics; this was a surprising finding. As noise bands increased, scores on math tests dropped; however, when adjusted for social deprivation, the statistical significance is lost. There appeared to be no effect on science. When scores in English were examined further, researchers found that there was an effect on reading, though not on spelling, handwriting, and writing. As for mathematics, there was a dose-response effect for reading. Results of the SATS study suggest that chronic exposure to aircraft noise is associated with school performance in reading and mathematics; because the mathematics results were so strong, the study suggests that the effects of noise may not be limited to language-based tasks. A dose-response function was identified for both effects; however, after adjusting for social deprivation, the effect is lost. The social deprivation question is very complex: it may be that social deprivation is the primary force in determining performance, that noise is a mediator serving to worsen the effect – in this case it would be wrong to adjust for social deprivation. On the other hand, it may be that social deprivation had a moderating affect on the relationship between aircraft noise and performance – noise causes deficit in cognition, but that is made worse in a situation of social deprivation. Researchers believe that there is a need to investigate whether there is a relationship between social deprivation and selection into noisy areas.

West London Schools Study This study is jointly funded by UK Department of Health and Department of Transport and Environment a larger study similar to the Schools Environment and Health Study. The aims of the study are to confirm that chronic levels of high aircraft noise exposure in children are associated with cognitive impairment, reading, memory, and attention. Stress responses are now being evaluated in terms of catecholamine secretion (a finding of the Munich Study), noise annoyance, and self-reported stress levels. The model will adjust for individual and school-level confounding factors. Researchers also want to look at issue of social deprivation. The study includes ten high-noise schools matched with 10 control schools; again, drawn from areas around Heathrow. Researchers will carry out analyses at school and individual level, and will conduct noise measurements at the time of testing at the schools. The study also will collect data on personal dosimetry on a sub-sample of the children, as well as an additional sub-sample to evaluate qualitative effects: How do they feel about noise? Preliminary results of the West London Schools Study suggest that children from high noise schools heard more aircraft noise and were more annoyed by aircraft noise than children from low noise schools, but did not differ substantially on road noise traffic annoyance. Further analyses will examine aircraft noise exposure in relation to cognitive outcomes, adjusting for confounding, and taking into account both individual and school level

factors.

ANSI Standard: David Lubman and Lou Sutherland

Mr. Sutherland and Dr. Lubman are co-chairs of Working Group 42 of the ANSI S-12 Noise Committee, which is working to develop a standard for classroom acoustics. The Working Group is working directly with the U.S. Access Board, who implements the Americans with Disabilities Act. This is significant because adoption by the Access Board carries the weight of law. The proposed standard will be applied primarily to new school construction, not for existing schools. The standard is still being developed, but will probably include the following elements:

- A limit for interior ambient noise in classrooms: the Swedish guidelines call for 30 dBA interior noise level, as does the American Speech, Language and Hearing Association.
- A limit for reverberation time in classrooms: e.g., 0.4-6 sec in rooms where speech is important (i.e., classrooms, auditoria).
- Minimum sound insulation between spaces.
- To deal with aircraft noise levels, the standard may take into account aircraft flyovers by identifying an acceptable Time Above threshold level – however, the threshold and amount of time have yet to be determined. The standard may also address an acceptable number of events in a certain time period.
- A noise measurement protocol, methods for performance validation, and design guides and checklists.

One of the major goals of the standard is to simplify it so that it is easy to implement and easy to measure at the individual school level.

ADDITIONAL RESEARCH

Presenters at the symposium believe that there are a number of areas where more research is needed. These include:

Dose-response functions, Thresholds, Metrics Researchers are now fairly confident that a relationship between noise and its effects on some aspects of learning exist. One of the major unresolved problems, though, is identifying a level at which aircraft noise is problematic, as well as identifying levels of *change* which result in changes in learning. Most of the studies have identified students as exposed to a "noisy" or "quiet" environment, with little regard given to developing a curve which shows responses at varying noise levels. There is one dose-response function for relating reading and noise, but it is difficult to translate to DNL.

Underlying Mechanisms and Processes An understanding of how the effect works is important for identifying policy, because if we understand what is causing the problem we may be able to develop more sophisticated and targeted policies and interventions.

More Thorough Psycho-acoustic Information Another related issue is the choice of noise metric: most studies have identified "noisy" environments based on DNL or Leq – it may be that these are not appropriate metrics for two reasons: first, both DNL and Leq were developed to address issues of annoyance, not cognitive development or health; and second, DNL imposes a nighttime penalty which is largely irrelevant for describing classroom noise levels, and may if fact, provide a misleading measure. Perhaps we should be looking at things such as speech interference levels (SIL) and reverberation times. More research needs to be conducted to identify which noise metrics are appropriate for measuring learning responses.

Vulnerability Many environmental regulations are built with a margin of safety; (e.g., air pollution levels include margin of safety to protect asthmatics); we have not given much thought to an analog for noise. More research

needs to be done on the effects of noise on specific, vulnerable populations, including children with lower aptitudes, children with hearing problems, and children who are learning in a non-native language. Should classroom noise standards build in a "margin of safety" to protect these vulnerable populations? • ***Ecological Perspective*** To date, most of the research has focused strictly on the children. Research should be expanded to address the entire learning environment, including the effects of noise on teachers' motivation and parents' motivation. A small amount of research suggests that there may be some changes in teacher and parent behavior in the presence of noise. Many of these studies also have a potential for confounding, for example poverty. Most of the research controls for these kinds of variables. However, what if poverty interacts with noise – what if noise, in the context of other situations, interacts with other affects to amplify them? In studies where we have controlled for socio-economic data, we may have understated some of the effects of noise. **RECOMMENDATIONS** FICAN makes the following recommendations: • ***Metrics*** Further work should be done to establish whether school day Leq is the appropriate measure for determining the effect of aircraft noise on classroom learning. An important question is the role of classroom interruptions. For example, would a teacher pausing for the flyover of an aircraft at x dB every 20 minutes have the same effect on classroom learning as pausing for an aircraft at x-10 dB every 2 minutes? Although the two cases would result in equal outdoor Leq, the interruption pattern would be different, and the effects on classroom learning could be different. At what indoor sound level does a teacher pause? Is SEL the best predictor of interruption? In posing these questions, the members recognize that such studies are difficult and expensive to perform, and none of the FICAN participants have funding for such research. Nor is it clear which agencies, if any, have a mandate to conduct such research. • ***Effectiveness of sound insulation*** In the absence of appropriations for specific research, FICAN encourages "before" and "after" evaluations of the effectiveness of noise mitigation in schools. In the past, the information on effectiveness of noise reduction in classrooms has been anecdotal rather than systematic. Through its website, FICAN is in a position to serve as a repository for "before" and "after" evaluations. FICAN invites noise-impacted communities, school boards, administrators, principles, teachers, and parents to address questions and information about "before" and "after" studies to our website. In conducting these evaluations, the following evaluators are recommended: (1) "Before" and "after" noise measurements in treated classrooms taken during school hours on days when classrooms are unoccupied. Guidelines for low-cost assessment of classroom noise will soon be available in the form of an American National Standards Institute publication. (2) "Before" and "after" academic scores, particularly for reading and math, from children using the treated classrooms. (3) "Before" and "after" teacher evaluations from teachers working in the treated classrooms. FICAN will undertake a pilot study to evaluate the effectiveness of school sound insulation programs in the following areas: (1) improved academic performance, as measured by standardized test scores; and (2) improved learning environments, as reported by classroom teachers. The study will also identify methods for conducting further research, if needed, and define the scope of the issue on a national basis. • ***Standards for classroom noise*** FICAN supports the development of an ANSI standard for classroom acoustics. FICAN encourages the working group to keep FICAN informed of progress on this matter. **REFERENCES** Bronzaft, A., and McCarthy, D. (1975). The effects of elevated train noise on reading ability. *Environment and Behavior*, 7 pp. 517-527. Green, K., Pasternack, B., and Shore, R (1982). Effects of aircraft noise on reading ability of school-age children. *Archives of Environmental Health*, 37, pp 24-31, 1982. Bullinger, M., Hygge, S., Evans, G.W., Meis, M., & von Mackensen, S. (1999). The psychological cost of aircraft noise for children. *Psychologische Beeinträchtigung von Kindern durch Fluglärm.*

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